Zwick / Roell

Intelligent Testing

Material Characterization of Advanced Composites

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28. testXpo

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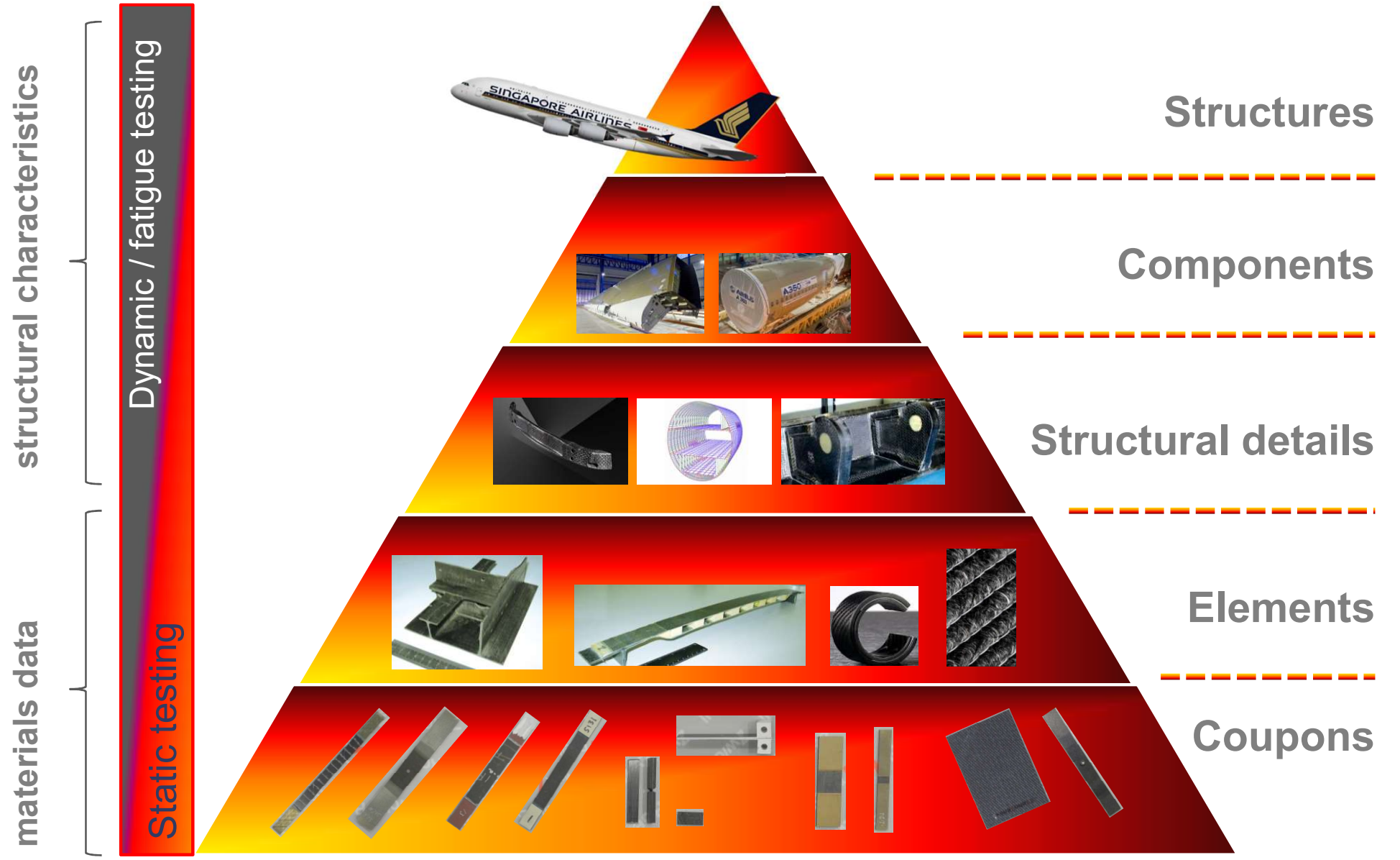
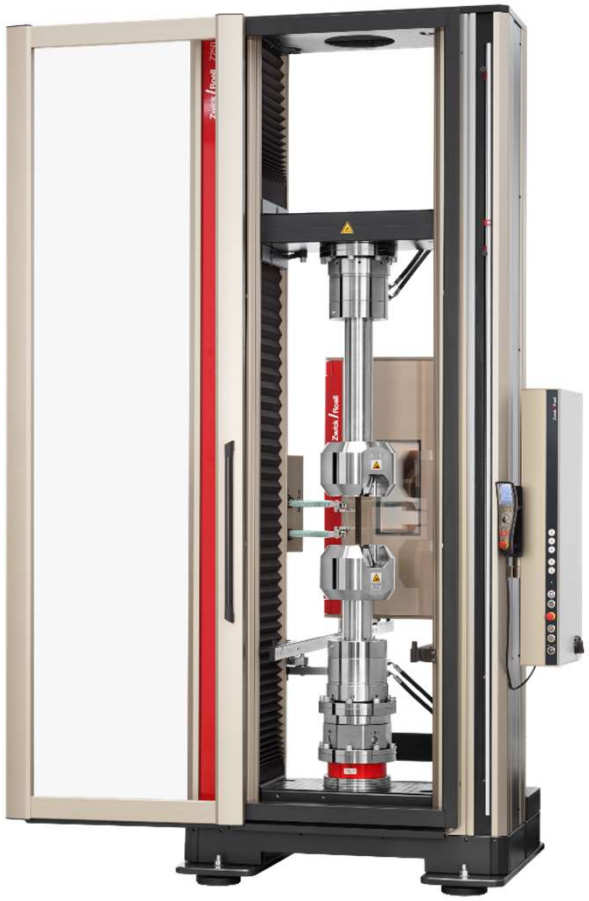
Test Pyramid

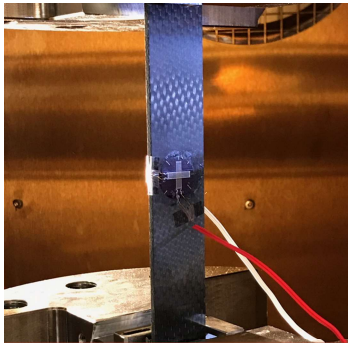


Standard Quasi-Static Testing

Material characterization starts on the ply level.



Tension



Tension

Compression

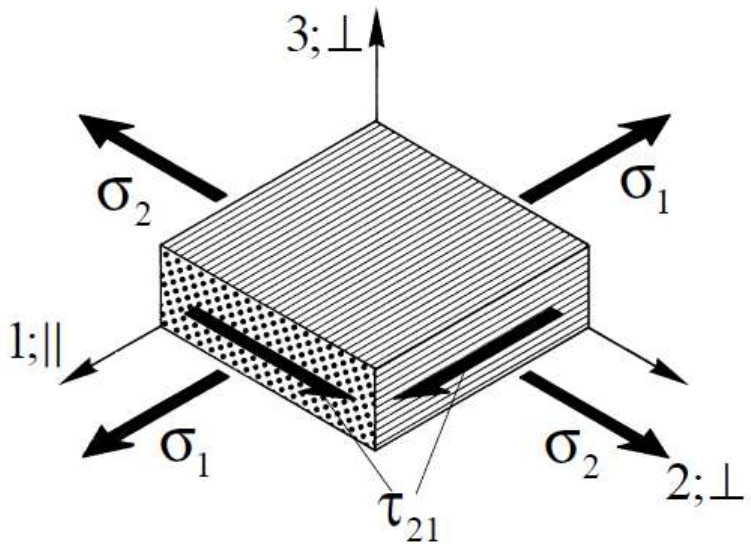
In-Plane-Shear (±45°)

Iosipescu-Shear

V-Notched Shear

Standard Quasi-Static Testing

The basic in-plane elastic properties of a composite ply are the foundation for material evaluation and design.

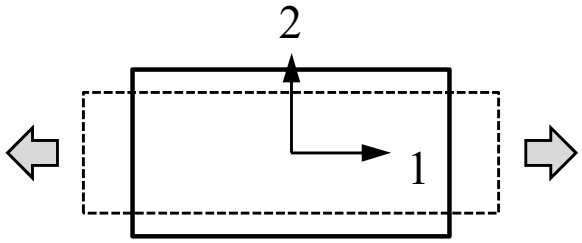


E_1 longitudinal modulus

E_2 transversal modulus

G_{12} in-plane shear modulus

ν_{12} Poisson ratio



[Schürmann. Konstruieren mit Faser-Kunststoff-Verbunden, Springer 2007]

Standard Quasi-Static Testing

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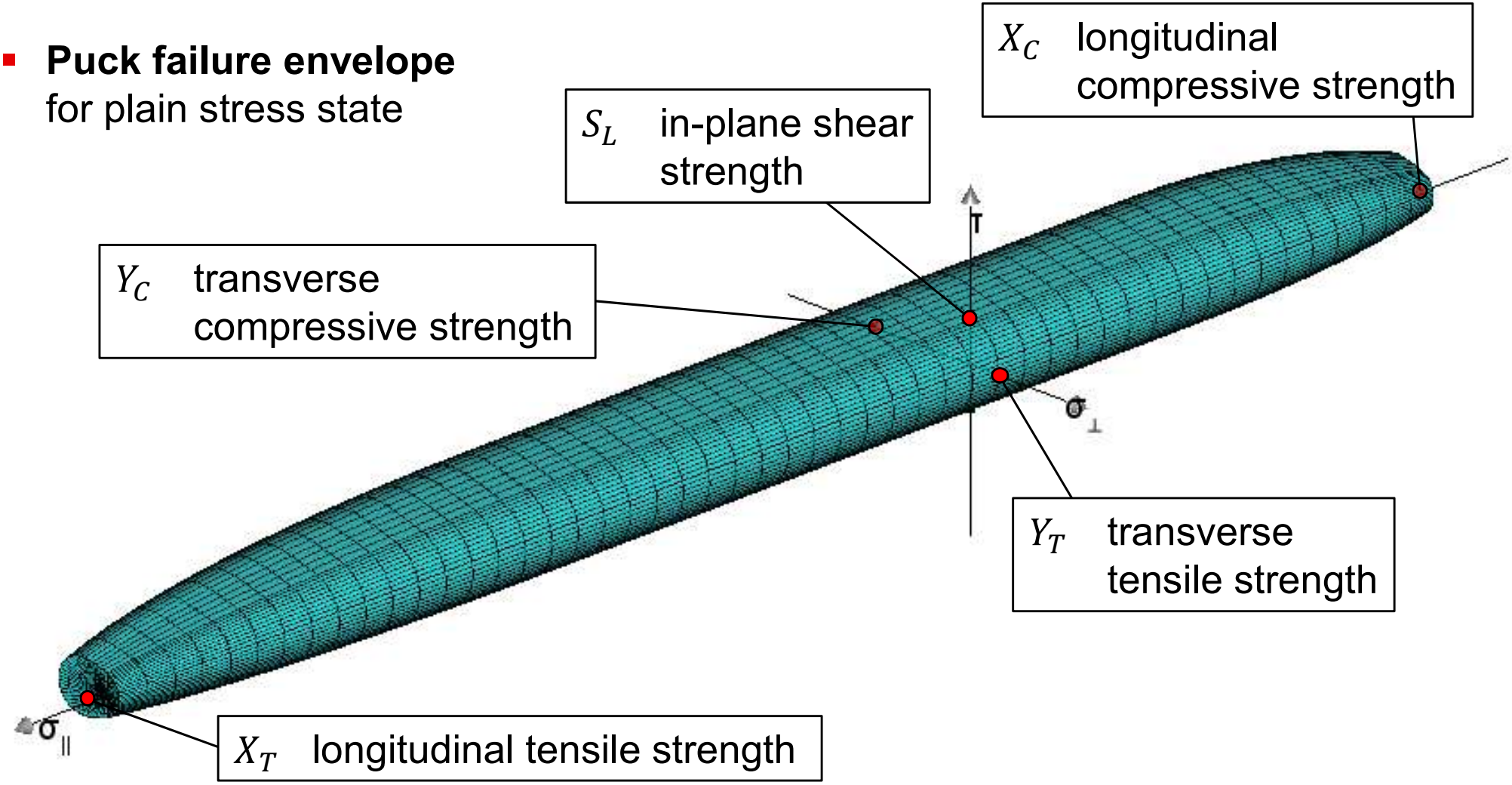
The independent strength properties of a composite ply define the cornerstones for failure criteria used in analysis and design.

- **Puck failure envelope**
  for plain stress state

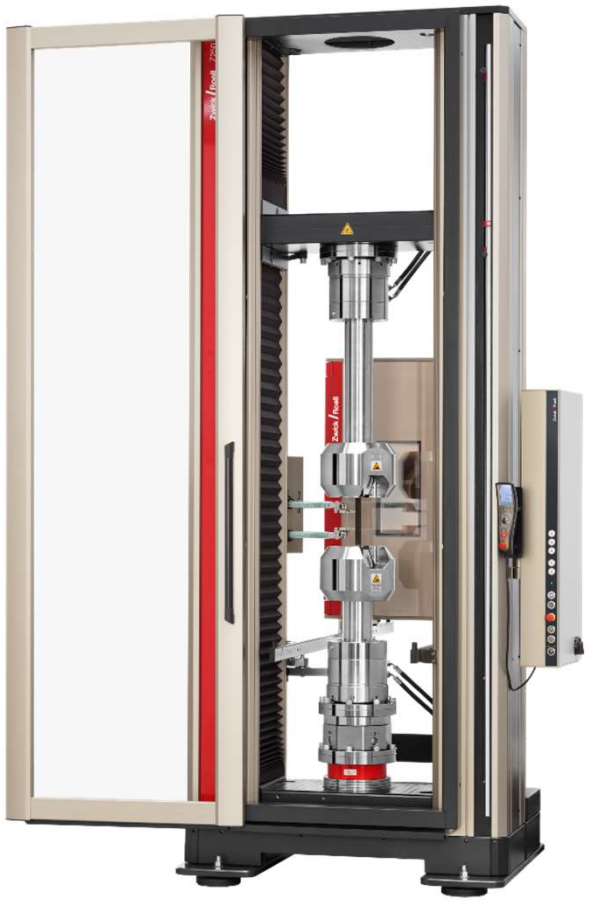


Standard Quasi-Static Testing

Zwick / Roell

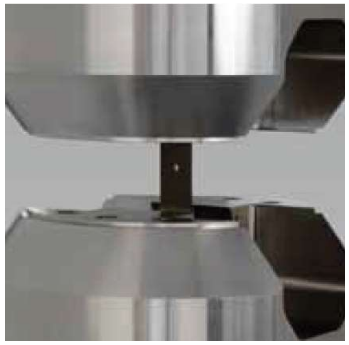
Further tests on the laminate level evaluate the influence of holes, fasteners and impact damage.

Simple tests are used for quality control.

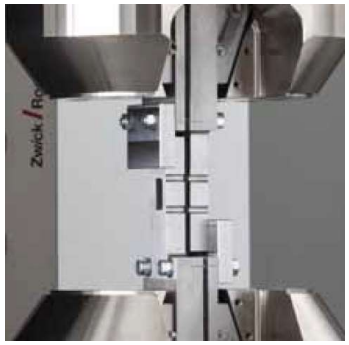


Quality Control

Open-Hole-Tension

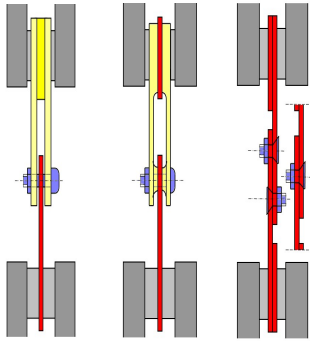


Open-Hole-Compression

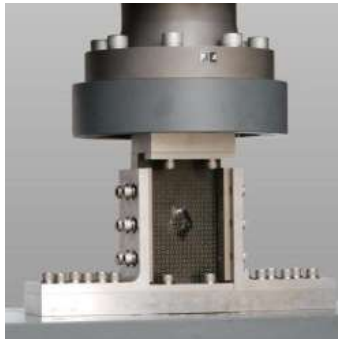


ILSS

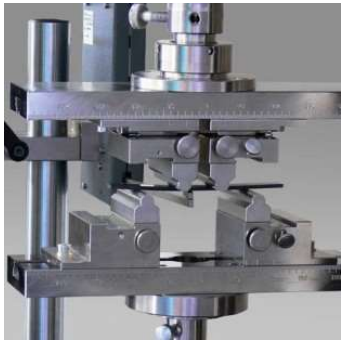
Bearing



CAI



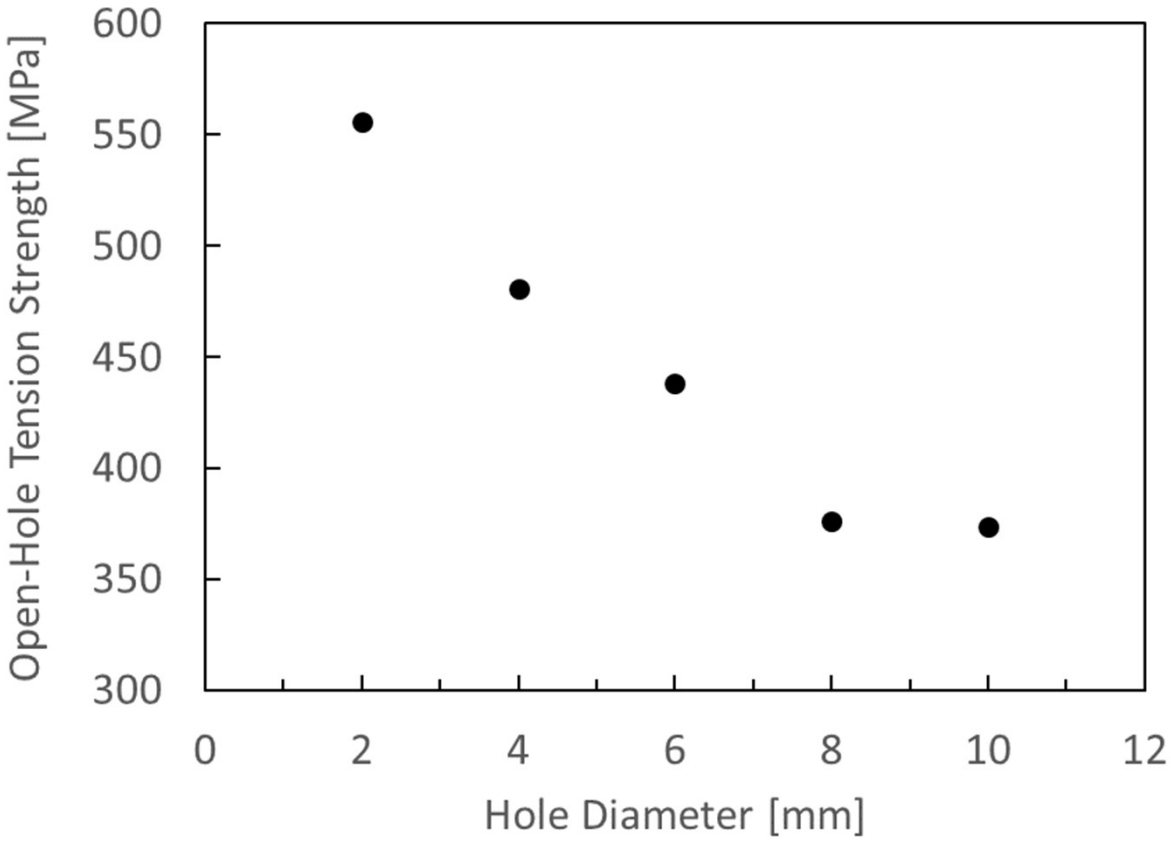
Bending



Standard Quasi-Static Testing

Open-hole tension and compression strength test generate important design allowables for aerospace structures.

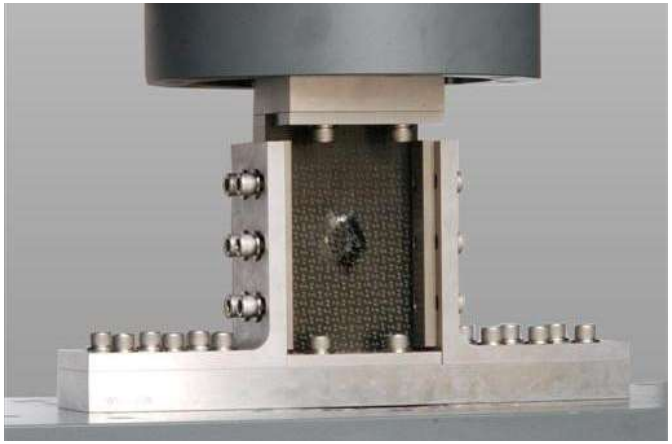
Open-hole tension test



after [Camanho et al. Composites A 43, 2012]

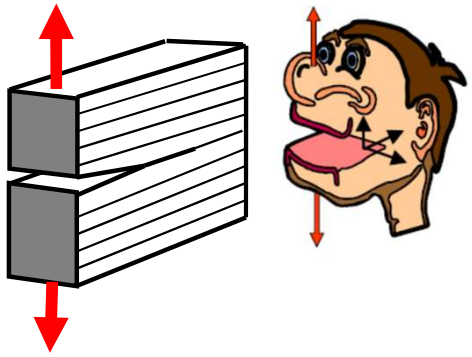
Standard Quasi-Static Testing

Damage tolerance for barely visible impact damage (BVID) is evaluated with the compression after impact (CAI) test.

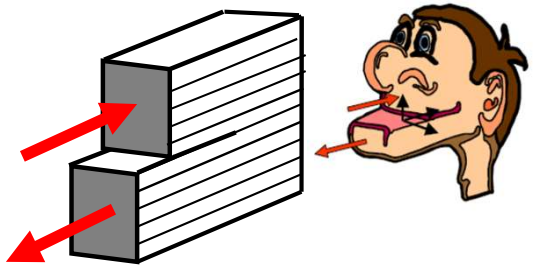


Standard Quasi-Static Testing

Characterization of interlaminar fracture toughness evaluates the weak-spot of layered composites.

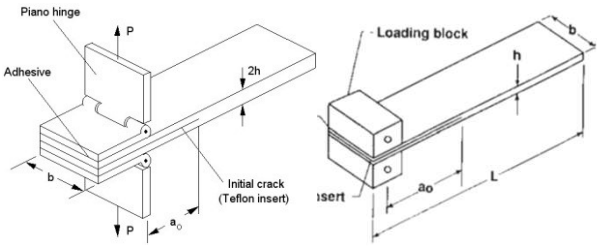


Mode I
Normal Crack Opening

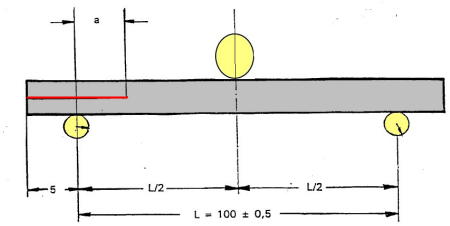


Mode II
Shear Crack Extension

Mixed Mode I+II



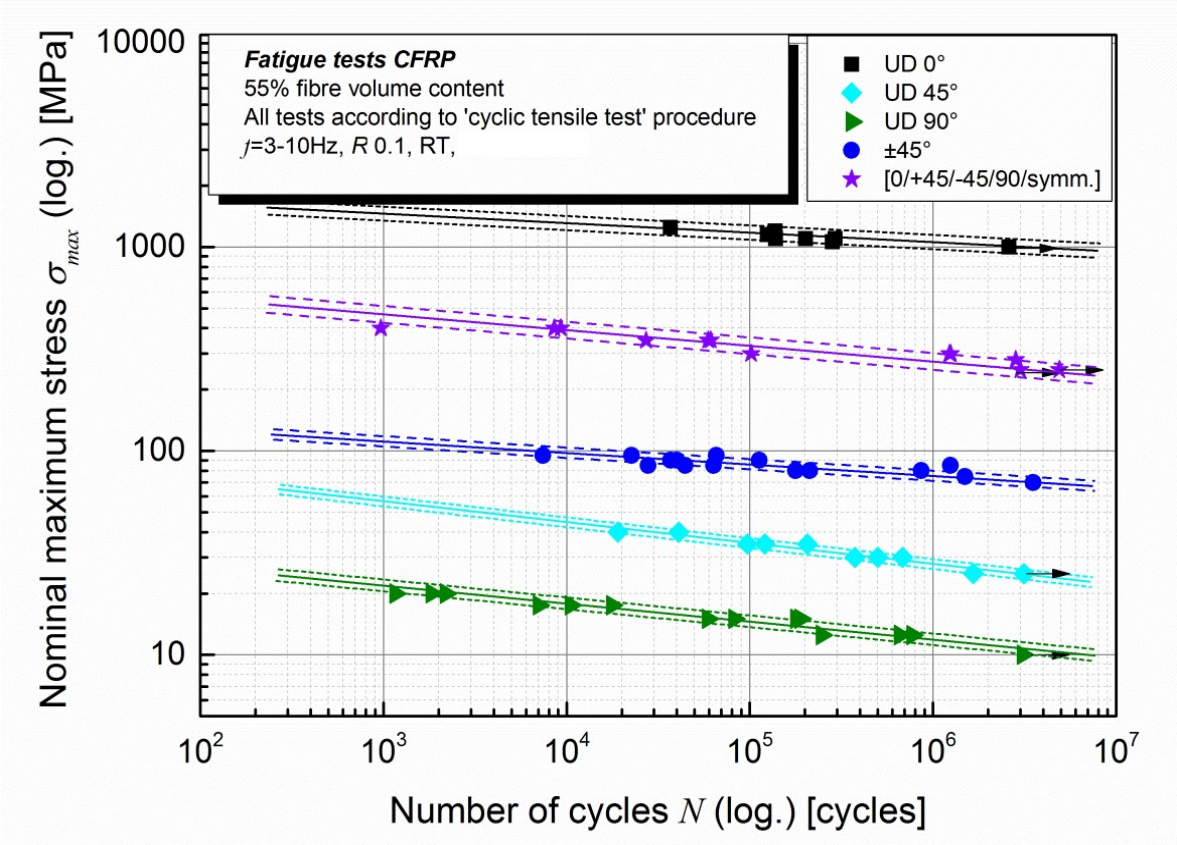
DCB
Double Cantilever Beam



ENF
End Notch Flexure

Fatigue Testing

Woehler line diagrams express the strength reduction under cyclic loading conditions.



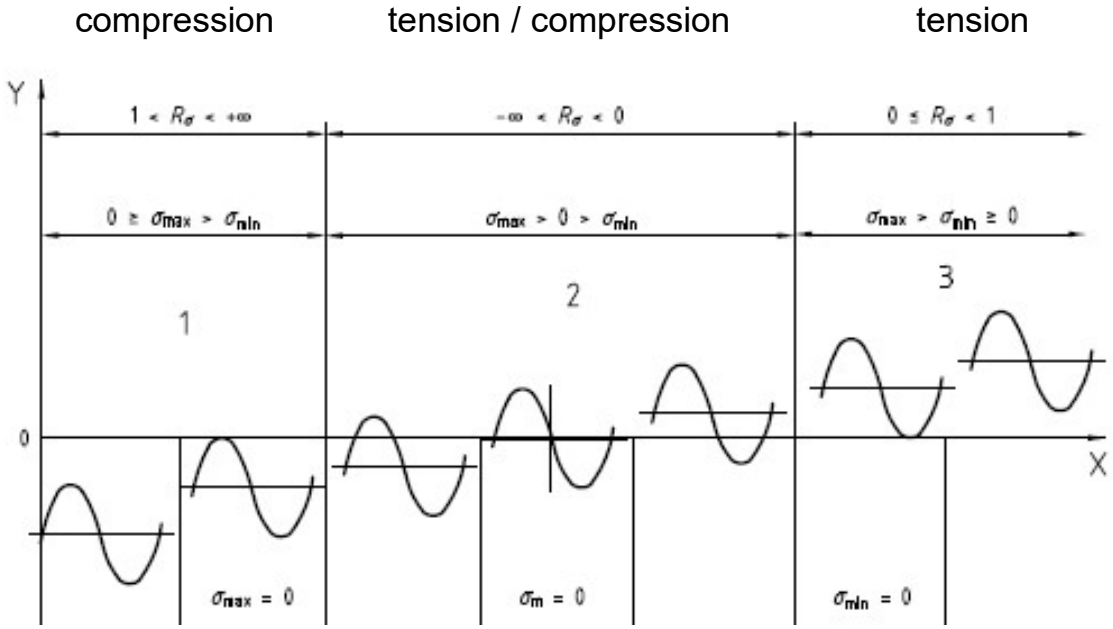
[G. Pinter. Montanuniversität Leoben]

Fatigue Testing

ZwickRoell offers a great variety of solutions for fatigue testing of composite materials.

▲
servohydraulic universal testing machines
up to 2500 kN

here: HC25 compact with integrated hydraulic unit

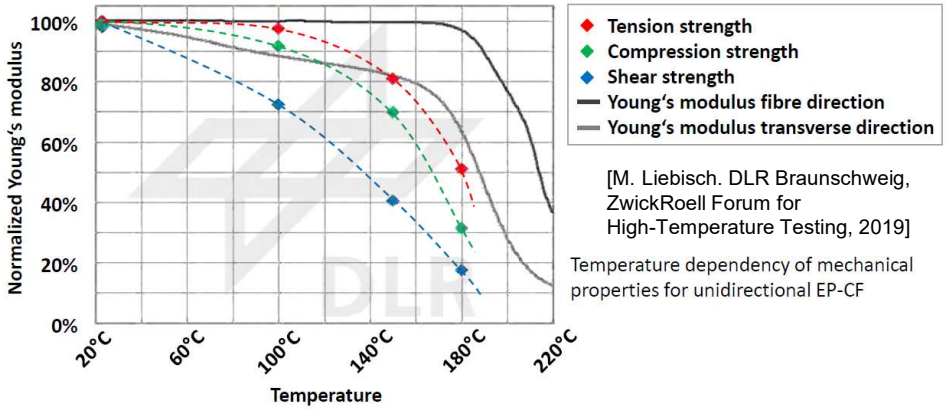


[ISO 13003:2003(E)]

◀ LTM electrodynamic testing machine
for fatigue testing up to 10 kN

Temperature Testing

The mechanical properties of fiber-reinforced polymer matrix composites are strongly temperature dependent.



[M. Liebisch. DLR Braunschweig, ZwickRoell Forum for High-Temperature Testing, 2019]

Temperature dependency of mechanical properties for unidirectional EP-CF

Temperature Testing

ZwickRoell has developed a modular system for non-ambient testing, covering 21 methods and about 120 test standards.

Tensile, OHT, FHT, Load Bearing, Lap Shear, In-Plane Shear

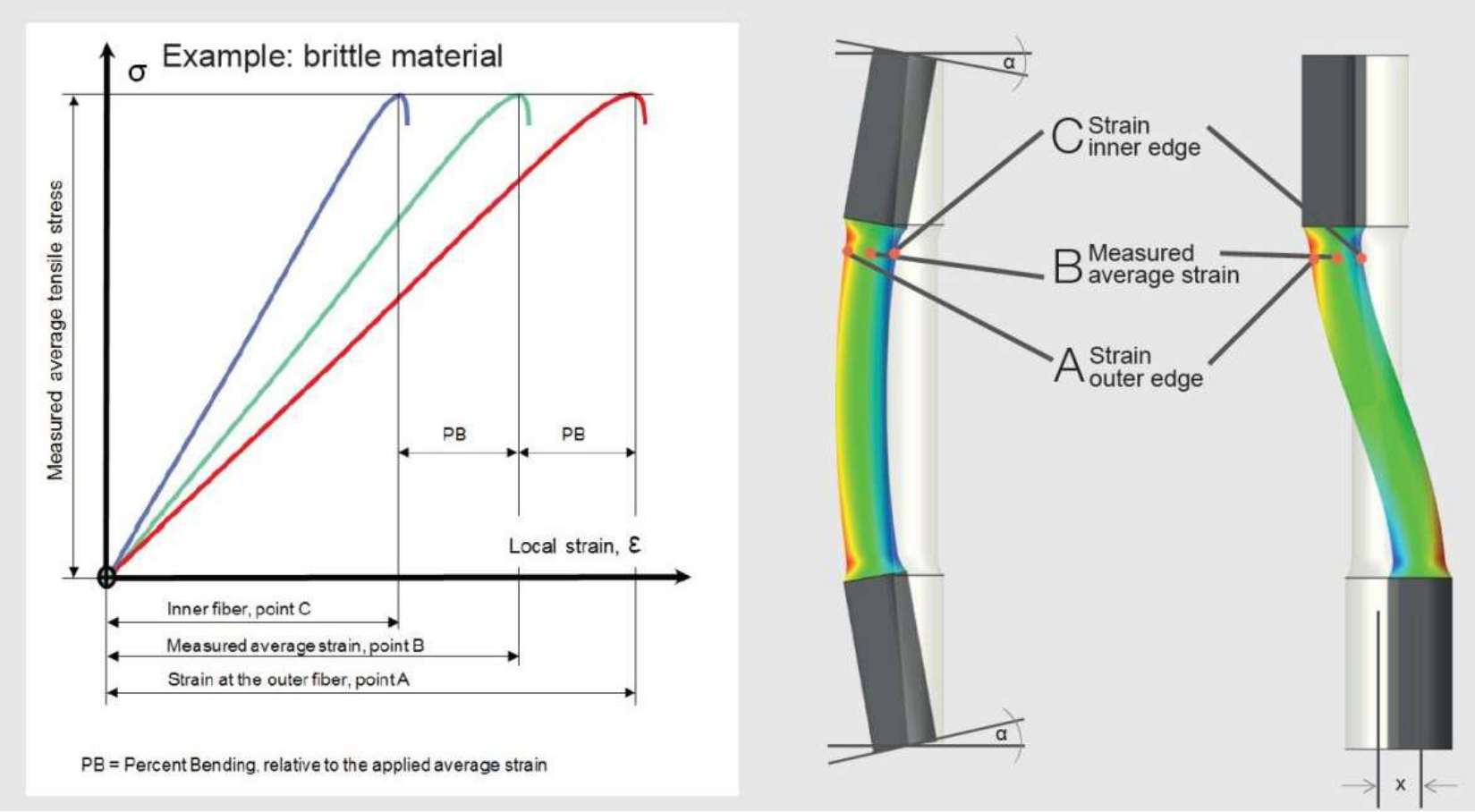
Testing in large temperature range from -70°C up to 360°C

Testing at ambient temperature

Alignment

Alignment errors strongly effect results for static tests with brittle materials as well as for fatigue and creep testing.

- Misalignments generate peak-strains and lead to apparently lower resistance

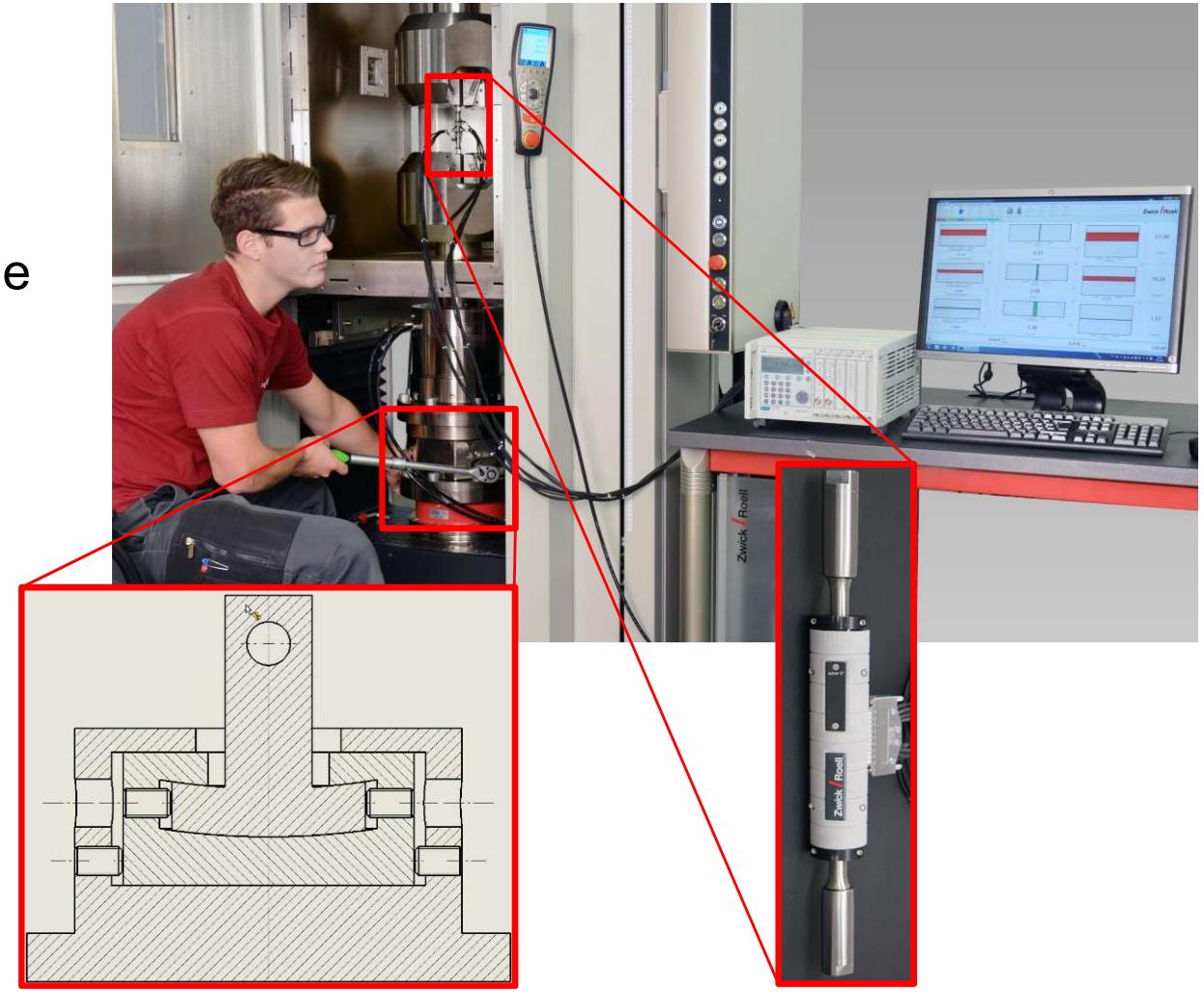


Alignment

The intelligent ZwickRoell alignment software (based on testXpert III) guides the alignment process in a perfect way.

The Alignment software

- **guides** the operator during the measuring procedure
- **controls** the testing machine
- **measures** the alignment error
- **supports** the operator aligning the grips via the alignment device
- **records** the alignment measuring results according to ASTM standards



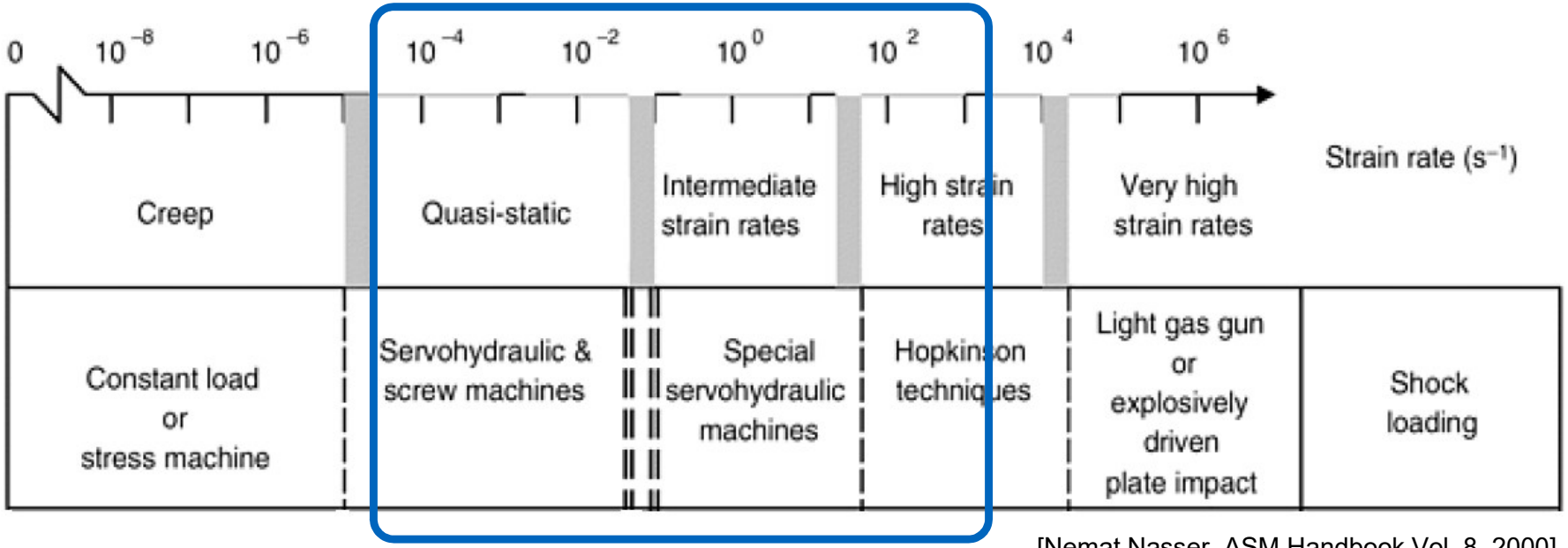
Speed of Loading

Polymer composites are strain rate dependent materials.

- Relevant strain rates for dynamic automotive and aerospace load scenarios

  automotive: quasi-static $\leq \dot{\varepsilon} \leq \approx 500\ s^{-1}$

  aeronautical: quasi-static $\leq \dot{\varepsilon} \leq \approx 1000\ s^{-1}$ (and higher)

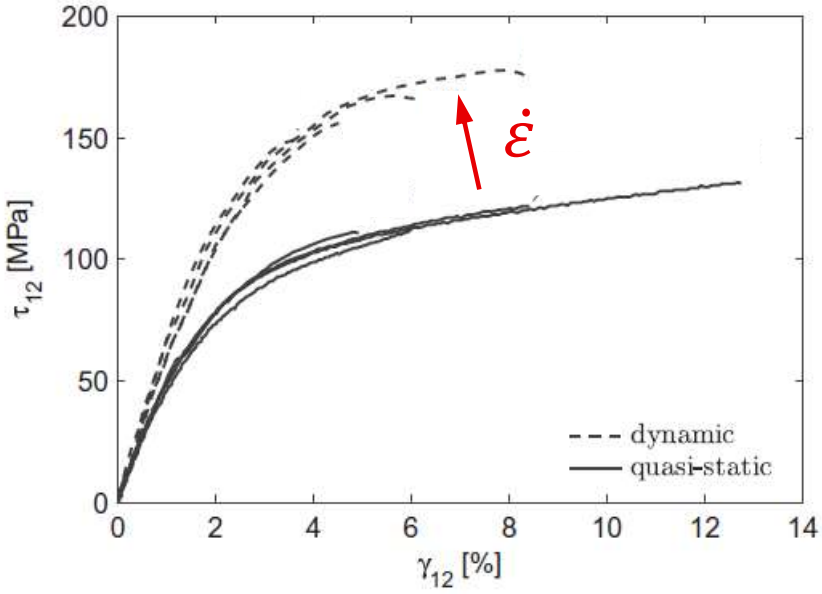


[Nemat Nasser, ASM Handbook Vol. 8, 2000]

Speed of Loading

Polymer composites are strain rate dependent materials.

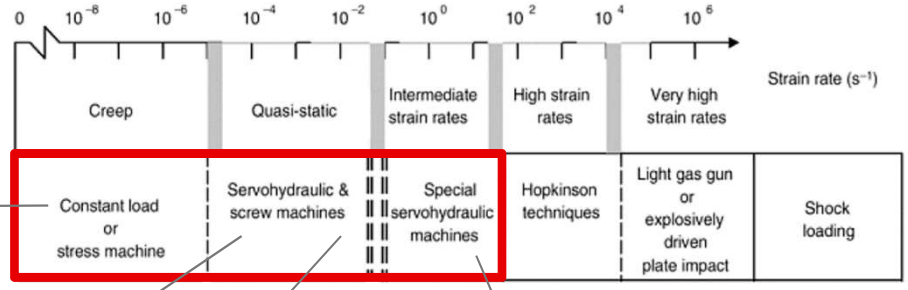
In-plane shear stress-strain response
of UD carbon-fiber-reinforced polymer



[Koerber et al. Mechanics of Materials 42 , 2010]

Speed of Loading

ZwickRoell offers a wide range of test machines for evaluation of the velocity-dependent material response of composites.



ZwickRoell offers a comprehesive range of standardized grips, fixtures and solutions to achieve reliable test results for composites.